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Drainage – Structure Correlation in tectonically active Regions: Case studies in the Bolivian and Colombian Andes

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It is widely accepted, that drainage patterns are often controlled by tectonics/climate and geology/rheology. Classical drainage patterns can be found 1) in fault-and-thrust belt, where rives follow the valleys parallel or cut perpendicular to strike trough the ridges, forming a trellis pattern, 2) at dome structures where the drainage form a radial pattern or 3) rectangular patterns in strongly fractured regions. In this study, we focus on fault-and-thrust belts, that undergone different phases of tectonic activity. According to classical models, the deformation is propagating into the foreland, hence being youngest at the frontal part and getting successively older towards the axis of the orogen. Drainage patterns in the more interior parts of the orogenic wedge should be then less influenced by the direction of structures, as landscape evolution is changing to a tectonic passive stage. This relationship might represent the transience and maturity of drainage pattern evolution.

Here we study drainage patterns of the Bolivian and the eastern Colombian Andes by comparing the relative orientation of the drainage network with the orogen structural grain. The drainage is extracted from Digital Elevation Models (SRTM 30 m) and indexed by their Strahler Order. Order 1 channels have an upstream area of 1 km^2. The direction of all segments is analyzed by linear directional mean function that results in the mean orientation of input channels with approx. 500 m average length. The orientation of structures for different structural domains is calculated using the same function on digitized faults and fold-axis. Rose diagrams show the length-weighted directional distribution of structures, of higher (>= 4) and of lower order (<= 3) channels.

The structural trend in the Bolivian Andes is controlled by the orocline, where a predominant NW-SE trend turns into an N-S trend at $\sim$18°S and where the eastern orogen comprise from west to east, the Eastern Cordillera (EC), the Interandean Zone and the Subandean Zone (SA), exhibiting a catchment relief of up to 5000 m. While the structural trend in the EC is predominately NW-SE with a uniform (no preferred orientation) distribution of lower order fluvial channels, it changes in the SA into a distinct N-S trend with a pronounced E-W orientation of lower order fluvial channels. A similar pattern is recognized in the Eastern Andes of Colombia, where the structural trend is NE-SW. The Eastern Cordillera comprise a frontal thin-skinned Neogene and Paleogene domain (FR) and the more interior lower Cretaceous an Upper Paleozoic thick-skinned region (IR). The trend of higher order channels is, as expected, parallel to the structures in the interior parts and perpendicular in the frontal part. However, the trend of lower order channels reveal no directional correlation to the structural trend in the interior, but a significant correlation to the structures in the frontal range that suffered relatively to the interior domains younger deformation phases.

We therefore postulate a dependency of the directional evolution of drainage patterns on the relative timing of tectonic activity. The only weakly preferred orientation of drainages in the interior parts (EC and IR) suggests a balance between structural control and drainage occupation, and higher maturity of the landscape. In contrast, the distinct pattern of drainages oblique to the structural grain in the frontal ranges (SA and FR) highlights the alignment of tributaries and suggests an ongoing tectonic control on drainage orientation. We test the hypothesis whether the correlation between the direction of small order rivers and the direction of structures can be used as a proxy for relative tectonic activity, which might be relevant in questions on 1) dominance of tectonics over climate, 2) dynamics of deformation propagation in fault-and-thrust-belts and 3) occurrence of higher erosion rates despite “limited” relief or threshold slopes. Ongoing efforts will investigate the possibility to quantify or compare relative tectonic activity across sites.